Optocoupler/Photocoupler

Lifetime of Optocoupler/Photocoupler

R08AN0015EJ0100
Rev.1.00
Aug. 30, 2024

Introduction

This application note describes about the basic theory of the lifetime of Optocoupler/Photocoupler[*1)] product, both for transistor output model and IC output model.

It will be also explained how to request specific lifetime data.

*1) In the following text, the term of Optocoupler is only used.

Contents

Basic structure of Optocoupler

1.1 Basic structure

1.1.1 Cross-sectional structure

An Optocoupler is a safety part that is electrically isolated and transmit signals.

To realize this function, the optocoupler is assembled with the LED, Light-Emitting-Diode, and the photodetector facing each other with a resin that transmits light in between as show in Figure1.1.

The input electrical signal is converted to an optical signal once, transmitted through the resin, isolated space, then converted back to an electrical signal and output.

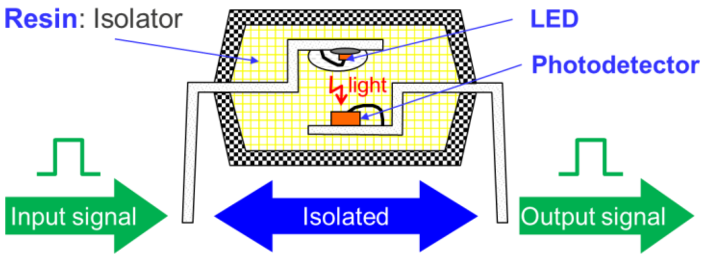

Figure 1.1 Schematic Cross-section of Optocoupler

1.1.2 LED and photodetector

The LEDs mounted on our optocouplers are made of GaAs or AlGaAs. On the other hand, photodetectors are Si products.

Even when operating within the rated specifications, quantum efficiency, photon ratio generated by electrons of input current (in another word the luminous efficiency) of an LED will decrease over time due to current and temperature stress at the PN junction.

Since the degradation of this LED is faster than that of the Si photodetector, LED is dominate in terms of semiconductor chip lifetime.

Our optocouplers are available in models with Transistor output ones and an IC output type, we are using several kinds of LEDs for both models to realize the required characteristics.

The following chapters explain the lifetime of these two types of products.

2. Lifetime of Optocoupler

2.1 Lifetime of Transistor output Optocoupler

2.1.1 CTR

CTR, Current Transfer Ratio, is a parameter that is similar to the DC current amplification factor (hFE) of transistor and represents the ratio of the output current (IC) to the input current (IF) as shown (1).

CTR = (IC / IF) × 100%   --- (1)

CTR is, alongside the dielectric strength voltage, one of the most important characteristics of transistor output Optocoupler. It is the item user must pay the most attention to when designing circuits.

CTR of an optocoupler depends mainly on four parameters below.

(i) Luminous efficiency of the LED.
(ii) Optical coupling factor between the LED and the photodetector (here by phototransistor).
(iii) Detection characteristics of the phototransistor.
(iv) Current amplification factor (hFE) of the phototransistor.

It is possible to estimate the lifetime of an optocoupler by determining the percentage of the decrease in CTR that can be tolerated under the same conditions.

2.1.2 Lifetime of Transistor output Optocoupler

The deterioration of the CTR, which is composed of these four parameters, depends mainly on the input current IF and the operating ambient temperature Ta.

For example, in the case of LED, the degradation of its luminous efficacy, which is indicated at (i) in the 2.1.1, over time depends on the current and temperature of the PN junction. We conduct long-term reliability tests for each LED that we adopted, in part, the package structure also taken into account, using multiple combinations of input current (IF) and operating ambient temperature (Ta).

From the results, we calculate each acceleration factor and are able to estimate the lifetime under actual usage conditions.

2.1.3 Request for Lifetime Data of Transistor output Optocoupler.

If you require life data, please contact our sales department or FAE, providing the product part number and the IF and TA required for the lifetime design.

We will submit life data in the format shown in Figure 2.1

Δ CTR is the change rates of the CTR, and defined in equation (2).

$$\Delta \mathrm{CTR}[\%] = \frac{\text{Over time change of CTR\%]}}{\text{initial CTR[\%]}} \quad \text{--- (2)}$$

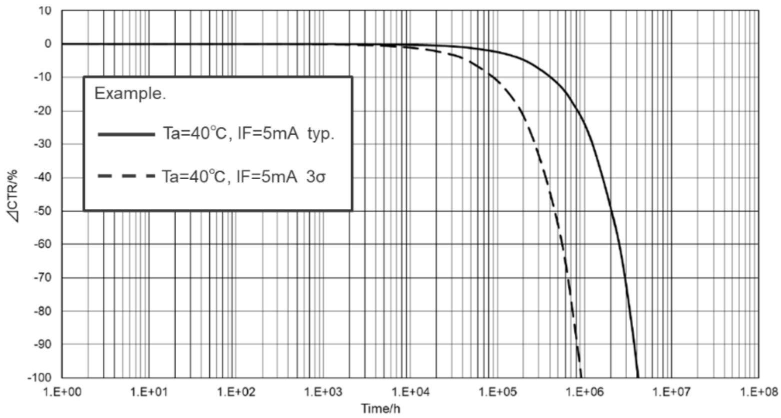

Figure 2.1 Examples of Lifetime data for Transistor output Optocoupler,

We can also accept requests for multiple combinations of IF and Ta.

From this graph, you can estimate the lifetime by designing how much the CTR can drop from the initial value.

Furthermore, the estimated life is inversely proportional to Duty and system operation rate as follows (3).

$$\text{Estimated Life} = \frac{\text{estimated lifetime at Duty (100\%)}}{\text{Actual Duty x System operation rate}} \quad \text{--- (3)}$$

2.2 Lifetime of IC output Optocoupler 1: Gate Driver and for Communication

2.2.1 IFHL, IFLH

For IC output type optocouplers, there is no CTR indicator since the processing is mainly digital in the photodetector IC. In the Gate Driver and Optocoupler for Communication case, the decrease in the LED's luminous efficiency is detected by the Threshold Input Current, IFHL or IFLH, and used to estimate its lifetime.

IFHL: Active Low output threshold current.
IFLH: Active High output threshold current.

IFHL or IFLH of an optocoupler depends mainly on three parameters below.

(i) Luminous efficiency of the LED.
(ii) Optical coupling factor between the LED and the photodetector (here by photodetector built-in IC).
(iii) Detection characteristics of the photodetector.

It is possible to estimate the lifetime of an optocoupler by determining the percentage of the decrease in IFHL or IFLH that can be tolerated under the same conditions.

2.2.2 Lifetime of IC output Optocoupler 1

The deterioration of the IFHL or IFLH, which is composed of these three parameters, depends mainly on the input current IF and the operating ambient temperature Ta in the same way as Transistor output optocoupler.

2.2.3 Request for Lifetime Data of IC output Optocoupler 1

If you require life data, please contact our sales department or FAE, providing the product part number and the IF and Ta required for the lifetime design.

We will submit life data in the format shown in Figure 2.2

Δ IFHL and ΔIFLH are the change rates of the IFHL and IFLH for each, and defined in equation (4) and (5).

$$\Delta \text{IFHL}[\%] = \frac{\text{Over time change of IFHL[mA]}}{\text{initial IFHL[mA]}} \quad \text{--- (4)}$$

$$\Delta \text{IFLH}[\%] = \frac{\text{Over time change of IFLH[mA]}}{\text{initial IFLH[mA]}} \quad \text{--- (5)}$$

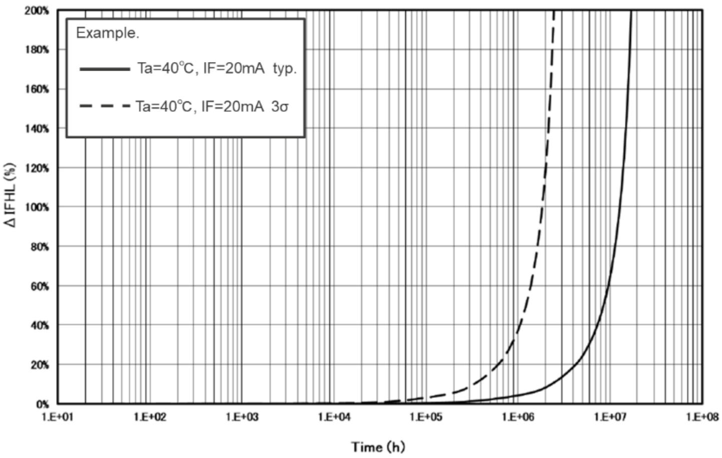

Figure 2.2 Examples of Lifetime data for IC output Optocoupler,

We can also accept requests for multiple combinations of IF and Ta.

From this graph, you can estimate the lifespan by calculating ΔIFHL[%] or ΔIFLH[%] at lifetime end as follows, (6) or (7).

$$\Delta \text{IFHL[\%] at lifetime end} = \frac{\text{Forward current IF[mA] designed by customer} - \text{initial IFHL[mA]}}{\text{initial IFHL[mA]}} \quad \text{--- (6)}$$

$$\Delta \text{IFLH[\%] at lifetime end} = \frac{\text{Forward current IF[mA] designed by customer} - \text{initial IFLH[mA]}}{\text{initial IFLH[mA]}} \quad \text{--- (7)}$$

The horizontal axis of the graph in this document shows the Lifetime when Duty is 100%.

Furthermore, the estimated life is inversely proportional to Duty and system operation rate as follows (8).

$$\text{Estimated Life} = \frac{\text{estimated lifetime at Duty (100\%)}}{\text{Actual Duty x System operation rate}} \quad \text{--- (8)}$$

2.3 Lifetime of IC output Optocoupler 2: Isolation Amp. and Sigma-Delta Modulator

In the case of the Isolation Amplifier and ΔΣ Modulator, the input is the voltage and current to be monitored, and since the LED drive circuit is built into the primary side, it is not possible to determine the lifespan based on IF.

We will provide you with lifetime data for the case where the most severe input conditions are continued, so please let us know the product part number.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Aug.30.24	—	Initial release

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